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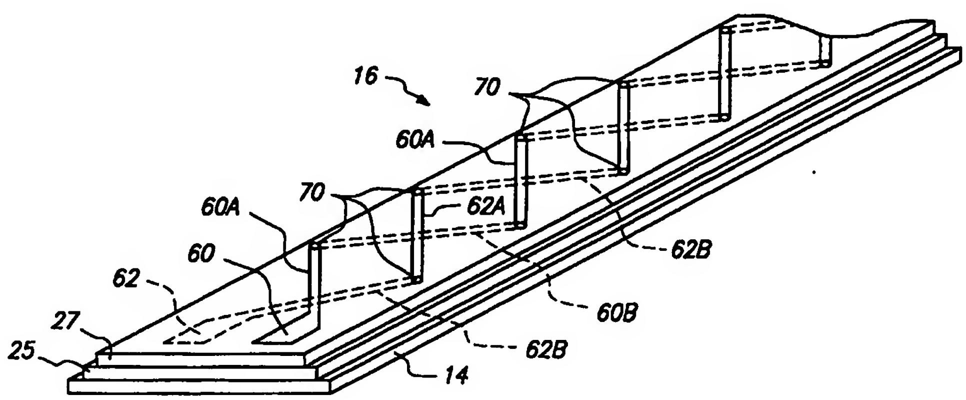
(54) Title: HEAD SUSPENSION WITH SELF-SHIELDING "TWISTED" INTEGRATED CONDUCTOR TRACE ARRAY



(57) Abstract

A head suspension (10) has an integrated two-layer trace conductor array (16) for supporting and electrically interconnecting a dual element read/write head (20) to electronic circuitry in a disk drive (30) while providing reduced susceptibility to electromagnetic interference and stray signal pickup. Two sets of trace segments (60, 62) on two layers (25, 27) are formed in a crossing, "twisted wire" pattern, and are connected into a two conductor signal path by vias (70) extending between the two layers. A laterally and elevationally transposed multi-conductor trace array (16A) is also described.

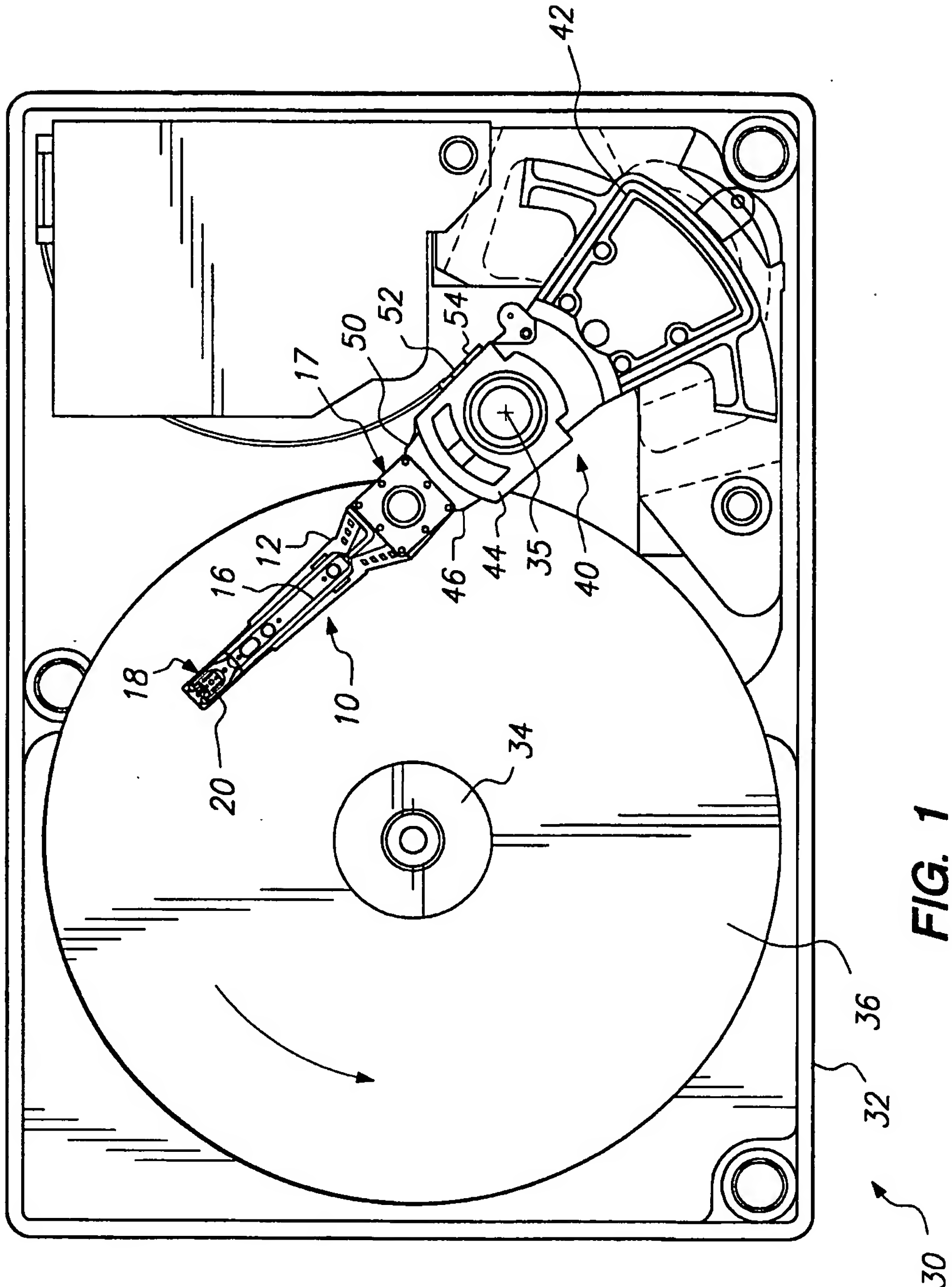


FIG. 1

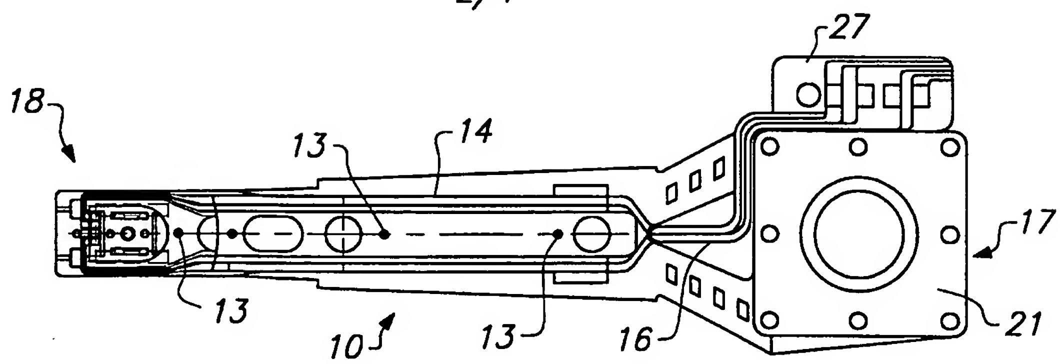


FIG. 2

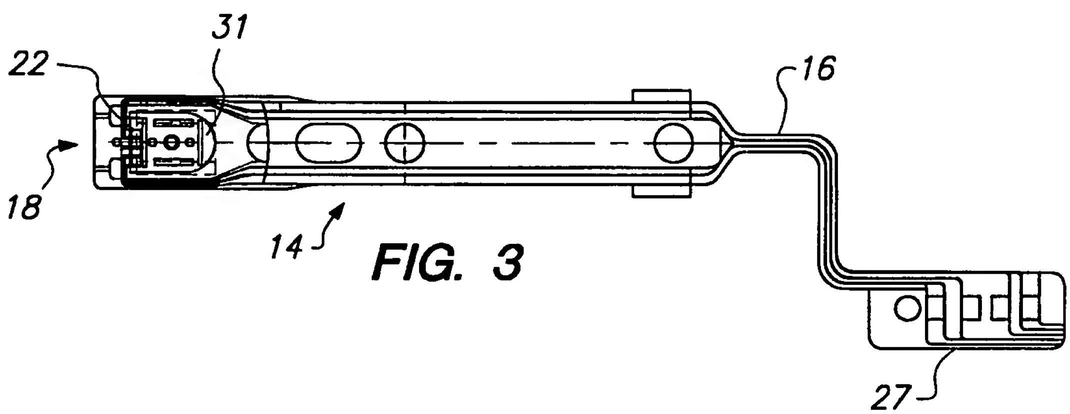


FIG. 3

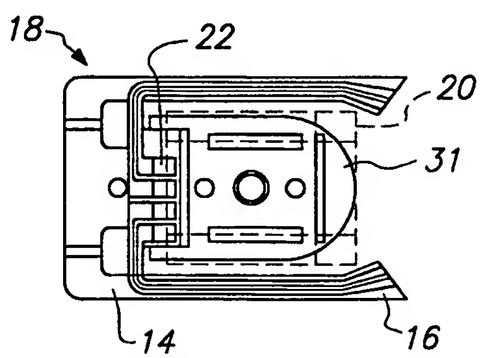


FIG. 3A

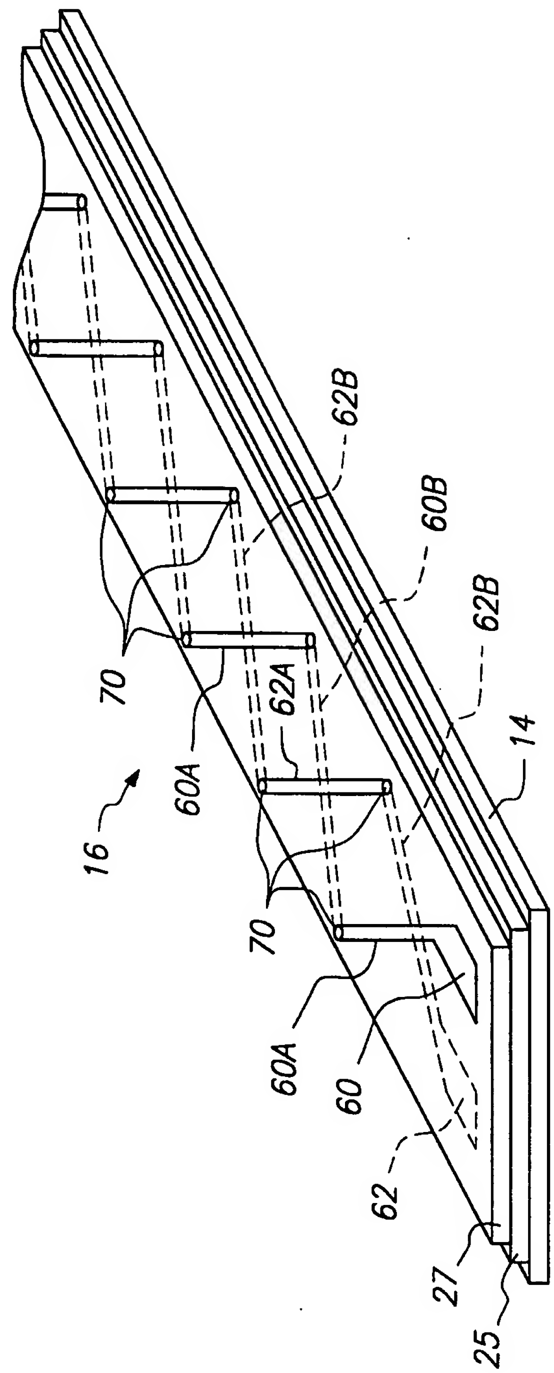


FIG. 4

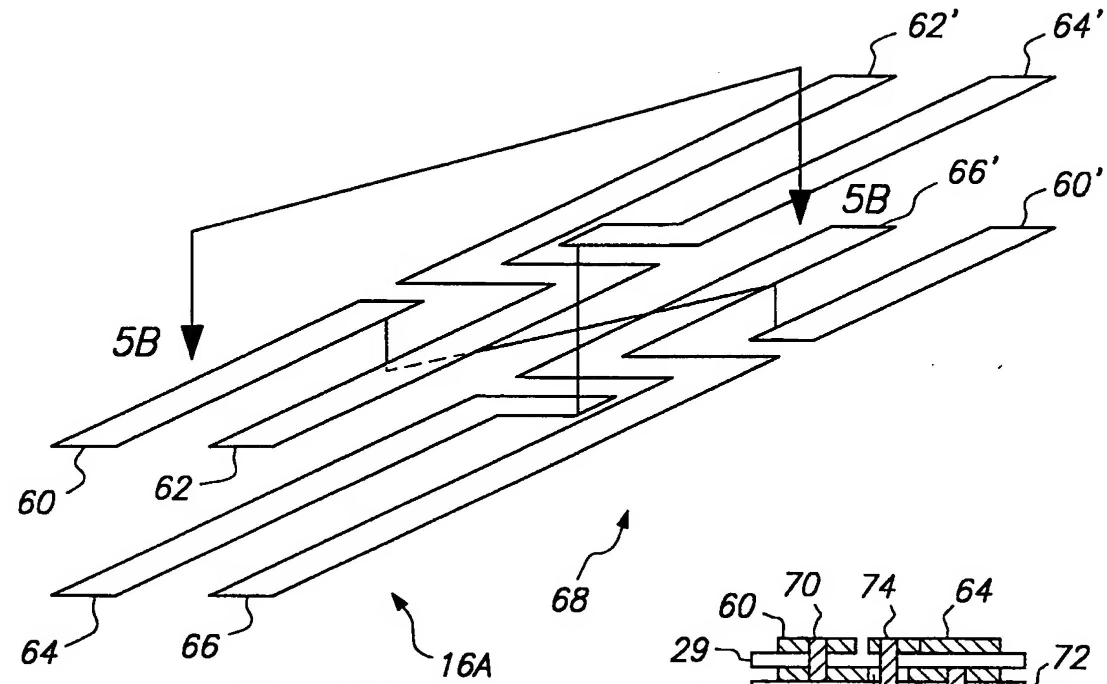


FIG. 5A

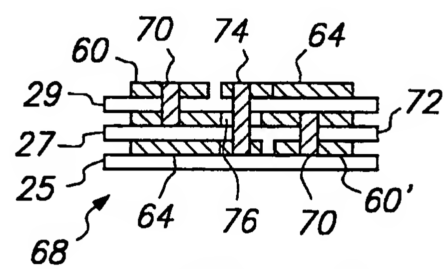


FIG. 5B

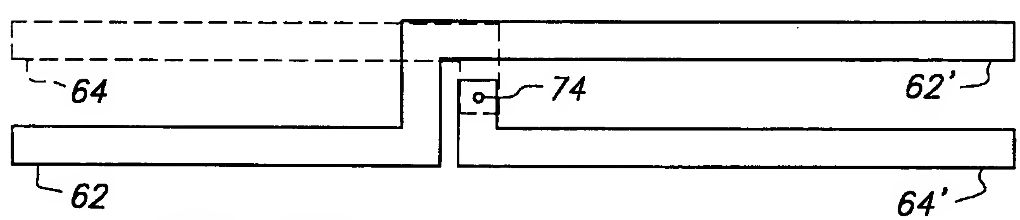


FIG. 5C

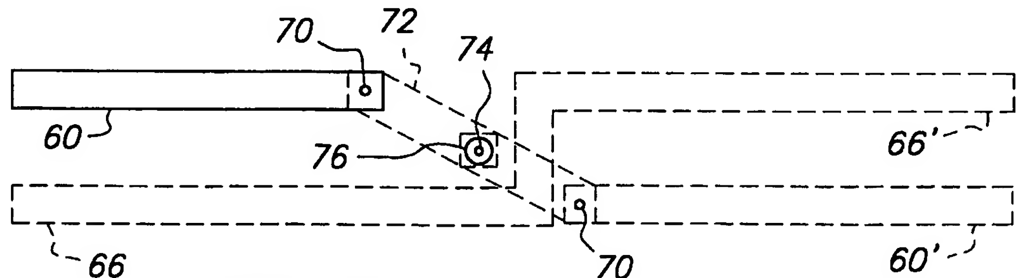


FIG. 5D

INTERNATIONAL SEARCH REPORT

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PCT/US97/20311

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 360/104, 106, 113, 123, 126

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,491,597 A (BENNIN ET AL.) 13 February 1996, see entire document.	1-14
Y	US 3,757,028 A (SCHLESSEL) 04 September 1973, see entire document.	1-14
A	US 5,039,824 A (TAKASHIMA ET AL.) 13 August 1991, see entire document.	1-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

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HEAD SUSPENSION WITH SELF-SHIELDING "TWISTED" INTEGRATED CONDUCTOR TRACE ARRAY

Reference to Related Applications

This application is related to copending U.S. Patent Application Serial No. _________, entitled: "Suspension with Integrated Conductors having Trimmed Impedance", and filed on the same date as the present application (Attorney Docket No. Q96-1025-US1) which is a continuation-in-part of U.S. Patent Application Serial No. 08/621,431, filed on March 25, 1996; copending U.S. Patent Application Serial No. __________, entitled: "Suspension with Multi-Layered Integrated Conductor Trace Array for Optimized Electrical Parameters", filed on October 3, 1996 (Attorney Docket No. Q96-1032-US1); copending U.S. Patent Application Serial No. 08/724,978, entitled: "Head Suspension with Self-Shielding Integrated Conductor Trace Array", filed on October 3, 1996 (Attorney Docket No. Q96-1036-US1); and copending U.S. Patent Application Serial No. 08/692,394, entitled: "Multi-Trace Transmission Lines for R/W Head Interconnect in Hard Disk Drive, filed on October 3, 1996. The disclosures of the foregoing commonly assigned applications are incorporated herein by reference.

Field of the Invention

This invention relates generally to structure and method for isolating select service loop pairs of a trace conductor array formed integrally with a flexure of a head suspension assembly from unwanted interference. More particularly, the present invention relates to an integrated suspension and conductor structure wherein the suspension traces are arranged and configured in a manner analogous to a twisted wire transmission pair in order to provide self-shielding of one or multiple signal pairs against unwanted electromagnetic noise (EMI) or radio frequency interference (RFI).

Background of the Invention

Contemporary disk drives typically include a rotating rigid storage disk and a head positioner for positioning a data transducer at different radial locations relative to the axis of rotation of the disk, thereby defining numerous concentric data storage tracks on each recording surface of the disk. The head positioner is typically referred to as an actuator. Although numerous actuator structures are known in the art, in-line rotary voice coil actuators are now most frequently employed due to their simplicity, high performance, and their ability to be mass balanced about their axis of rotation, the latter being important for making the actuator less sensitive to perturbations. A closed-loop servo system within

the disk drive is conventionally employed to operate the voice coil actuator and thereby position the heads with respect to the disk surface.

The read/write transducer, which may be of a single or dual element design, is typically deposited upon a ceramic slider structure having an air bearing surface for supporting the transducer at a small distance away from the surface of the moving medium. Single write/read element designs typically require two wire connections while dual designs having separate reader and writer elements require four wire connections. Magnetoresistive (MR) heads in particular generally require four wires. The combination of an air bearing slider and a read/write transducer is also known as a read/write head or a recording head.

Sliders are generally mounted to a gimbaled flexure structure attached to the distal end of a suspension's load beam structure. A spring biases the load beam and the head towards the disk, while the air pressure beneath the head pushes the head away from the disk. An equilibrium distance defines an "air bearing" and determines the "flying height" of the head. By utilizing an air bearing to support the head away from the disk surface, the head operates in a hydrodynamically lubricated regime at the head/disk interface rather than in a boundary lubricated regime. The air bearing maintains a spacing between the transducer and the medium which reduces transducer efficiency. However, the avoidance of direct contact vastly improves the reliability and useful life of the head and disk components. Demand for increased areal densities may nonetheless require that heads be operated in pseudo contact or even boundary lubricated contact regimes, however.

Currently, flying heights are on the order of 0.5 to 2 microinches. The magnetic storage density increases as the head approaches the storage surface of the disk. Thus, a very low flying height is traded against device reliability over a reasonable service life of the disk drive. At the same time, data transfer rates to and from the storage surface are increasing; and, data rates approaching 200 megabits per second are within practical contemplation.

The disk drive industry has been progressively decreasing the size and mass of the slider structures in order to reduce the moving mass of the actuator assembly and to permit closer operation of the transducer to the disk surface, the former giving rise to improved seek performance and the latter giving rise to improved transducer efficiency that can then be traded for higher areal density. The size (and therefore mass) of a slider is usually characterized with reference to a so-called standard 100% slider ("minislider").

The terms 70%, 50%, and 30% slider ("microslider", "nanoslider", and "picoslider", respectively) therefore refer to more recent low mass sliders that have linear dimensions that are scaled by the applicable percentage relative to the linear dimensions of a standard minislider. Smaller slider structures generally require more compliant gimbals, hence the intrinsic stiffness of the conductor wires attached to the slider can give rise to a significant undesired bias effect.

Very small diameter twisted solid wires have typically been used to connect head elements formed on sliders to other signal carrying and processing structures within the disk drive. The two conductors of a twisted pair service loop are inherently shielded from external noise sources such as EMI and RFI by virtue of the fact that the conductors are twisted around each other. Coaxial transmission line cables are also inherently self-shielding, but the center conductor is electrically unbalanced with respect to the outer cylindrical shield conductor.

To reduce the effects of this intrinsic wire stiffness or bias, integrated flexure/conductor structures have been proposed which effectively integrate the wires with an insulating flexible polymeric resinous flexure such that the conductors are exposed at bonding pads positioned at the distal end of the flexure in the proximity of the head. U.S. Patent No. 5,006,946 to Matsuzaki discloses an example of such a configuration. U.S. Patent No. 5,491,597 to Bennin et al. discloses a further example in point. While such wiring configurations do enjoy certain performance and assembly advantages, the introduction of the disclosed flexible polymeric resinous material in the flexure and gimbal structure raises a number of challenging design issues. For example, the thermal expansion properties of the resinous material is not the same as the prior art stainless steel structures; and, the long-term durability of such resinous structures, including any requisite adhesive layers, is unknown. Therefore, hybrid stainless steel flexure and conductor structures have been proposed which incorporate most of the benefits of the integrated conductor flex-circuit flexure structures while remaining largely compatible with prior art fabrication and load beam attachment methods. Such hybrid designs typically employ stainless steel flexures having deposited insulating and conductive trace layers for electrical interconnection of the head to the associated drive electronics, e.g., a proximately located preamplifier chip and downstream read channel circuitry typically carried on a circuit board (along with other circuitry) attached to the head/disk assembly.

As taught by U.S. patent No. 5,491,597 to Bennin et al., entitled: "Gimbal Flexure and Electrical Interconnect Assembly", the disclosed prior approach called for use

of a spring material for the conductive trace layers, such as beryllium-copper alloy, which admittedly has higher electrical resistance than pure annealed copper, for example. On the other hand, pure annealed copper, while a satisfactory electrical conductor at high frequencies, also manifests high ductility rather than spring-like mechanical resilience, and therefore lacks certain mechanical spring properties desired in the interconnect trace material. Traces formed of pure copper plated or deposited onto e.g. a nickel base layer provide one alternative to the beryllium-copper alloy relied upon by the Bennin et al. approach.

These hybrid flexure designs employ relatively lengthy parallel runs of conductor trace pairs or four-wire sets which extend from bonding pads at the distal, head-mounting end of the flexure to the proximal end of the flexure, to provide a conductive path from the read/write head along the length of the associated suspension structure to the preamplifier or read-channel chip(s). Because the conductive traces of a service loop are typically formed in a side-by-side arrangement on a dielectric layer of the trace array, the traces can act as pick-up antennas, and the self-shielding advantages obtained from twisted wire pair arrangements are not available. A service loop formed of two side-by-side or vertically aligned traces remains susceptible to noise from e.g. EMI or RFI sources within or external to the disk drive.

While the Bennin et al. '597 patent discussed above includes an embodiment of Figs. 6-8 calling for stacking of traces to form a multi-level array of trace sets in order to handle a large number of signals, there is no teaching or suggestion within Bennin et al. '597 to arrange the conductor traces of multiple signal loops in an overlapping, twisted-pair arrangement providing desired immunity from crosstalk.

The invention to be described provides, inter alia, a flexure for a suspension in a disk drive which includes a multiple layered integrated conductor array arranged to provide a high level of immunity to electromagnetic interference and the like.

Summary of the Invention with Objects

A general object of the present invention is to provide a low-profile, robust and reliable high performance suspension assembly having an integral conductor trace array having plural conductive paths in multiple layers laterally and elevationally transposed to reduce cross-talk in a signal path configuration for electrically interconnecting a read/write head to associated read/write circuitry in a manner overcoming limitations and drawbacks of the prior art.

Another object of the present invention is to realize crosstalk-reduced geometries for a multi-path, multi-layer trace array interconnecting a flying head and an electronic circuit within a hard disk drive.

In accordance with principles of the present invention, an integrated flexure/conductor structure is provided for supporting a multi-element read/write head/slider assembly adjacent to a storage medium and for electrically interconnecting a read element of the head to read circuitry and a write element of the head to write circuitry. The structure comprises a generally planar conductive flexure member having a gimbal for supporting the read/write head/slider structure in proximity to a relatively moving data storage disk. A first electrical insulation layer is disposed on the flexure member. A first plurality of electrical trace segments is disposed on the first electrical insulation layer. A second electrical insulation layer is disposed over the first plurality of electrical trace segments. A second plurality of electrical trace segments is disposed on the second electrical insulation layer. Plural segment interconnects, such as transverse vias passing through at least the second electrical insulation layer interconnect the first and second pluralities of trace segments in a predetermined transpositional interconnection arrangement to form a multi-layer conductor pair. In one preferred form, the arrangement follows a criss-cross geometry for each conductor pair. In another preferred form, the arrangement provides e.g. a four-path arrangment having elevational as well as lateral trace segment transpositions for reducing electromagnetic interference.

These and other objects, advantages, aspects, and features of the present invention will be more fully appreciated and understood upon consideration of the following detailed description of preferred embodiments presented in conjunction with the accompanying drawings.

Brief Description of the Drawings

In the Drawings:

Fig. 1 is an enlarged, diagrammatic plan view of a disk drive including a suspension assembly having a multi-layer conductive trace array incorporating principles of the present invention.

Fig. 2 is an enlarged diagrammatic plan view of a preferred embodiment of integrated flexure/conductor load beam structure having tuned conductive traces in accordance with principles of the present invention.

Fig. 3 is an enlarged plan view of a flexure of the Fig. 2 load beam structure having integral wiring incorporating the tuned conductive trace array.

Fig. 3A is a greatly enlarged plan view of a read/write head connection region of the Fig. 3 flexure trace array and wherein the head slider is shown in dashed line outline.

Fig. 4 is a greatly enlarged diagrammatic view in isometric projection of a further self-shielding embodiment of the invention similar to the Fig. 3B embodiment but in which write traces are located in layers above and below a central layer for the read trace service loop pair.

Fig. 5A is a greatly enlarged diagrammatic view in isometric projection of a self-shielding four-path trace array which is laterally and elevationally transposed in accordance with principles of the present invention.

Fig. 5B is a sectional view in elevation of the four-path trace array taken along line 5B-5B in Fig. 5A.

Fig. 5C is a diagrammatic plan view showing lateral and elevational transposition of a first pair of conductive paths of the Fig. 5A array.

Fig. 5D is a diagrammatic plan view showing lateral and elevational transposition and bridge segment interconnection of a second pair of conductive paths of the Fig. 5A array.

Detailed Description of Preferred Embodiments

Referring to the drawings, where like characters designate like or corresponding parts throughout the views, Fig. 1 presents a diagrammatic top plan view of a head/disk assembly (HDA) of a hard disk drive 30. The hard disk drive 30 employs at least one load beam assembly 10 having a flexure 14 including a self-shielding trace interconnect array 16 embodying principles of the present invention. Fig. 1 shows the load beam assembly 10 with the flexure 14 and trace interconnect array 16 employed within its intended operating environment.

In the present example disk drive 30 includes e.g. a rigid base 32 supporting a spindle 34 (and spindle motor, not shown) for rotating at least one storage disk 36 in a direction shown by the curved arrow. Drive 30 also includes a rotary actuator assembly 40 rotationally mounted to the base 32 at a pivot point 35. The actuator assembly 40 includes a voice coil 42 which, when selectively energized by control circuitry (not shown), moves and thereby positions an actuator E-block 44 and head arms 46 (and load beam assemblies 10) at radial track positions defined on the facing surfaces of storage disks 36. At least one of the load beam assemblies 10 is secured at its proximal end 17 to a distal end of a head arm 46, e.g. by conventional ball-swaging techniques.

Conventionally, but not necessarily, two load beam assemblies 10 are attached to head arms 46 between disks 36; and, one load beam structure 10 is attached to head arms above and below the uppermost and lowermost disks of a disk stack comprised of multiple disks 36 spaced apart on spindle 34. The self-shielding interconnect structure 16 connects to a flexible trace/film segment 50 which extends to a ceramic hybrid circuit substrate 52 secured to a side of the E-block 44. The ceramic hybrid circuit 52 secures and connects a semiconductor chip 54 forming a read preamplifier/write driver circuit. Most preferably, the chip 54 is nested between the ceramic substrate of the hybrid circuit 52 and the E-block sidewall, and is secured to the sidewall by a suitable conductive adhesive or thermal transfer compound such that heat generated during operation of the chip 54 is dissipated into the E-block by conduction, and outwardly into the ambient air volume by convection.

As shown in Figs. 2, 3, and 3A, the load beam assembly 10 includes a generally planar formed stainless steel load beam 12 and a flexure 14. In the present example, the flexure 14 is formed of thin stainless steel sheet material which is e.g. approximately 20-microns thick. An array of e.g. two "twisted" conductive traces 60 and 62 formed of trace links each being approximately 10-microns thick copper conductor are interconnected to form an interconnect structure 16 which extends from the proximal end 17 of flexure 14 to another connection pad array 22 located at the slider-supporting distal end 18 of the load beam assembly 10. A transducer head slider 20 is attached to the gimbal 14 by a suitable adhesive at the distal end 18 of the load beam structure 10. The four connection pads 22 at the distal end 18 are provided for connection by e.g. ultrasonically-welded gold ball bonds 56 to four aligned connection pads 24 of a dual-element (four conductor) thin film magneto-resistive read/write structure 26 formed on a trailing edge of the slider body 20. Preferably, although not necessarily, the slider body 20 is a 30% slider. Larger and

smaller slider bodies, e.g. 50% and 20% sliders are within the contemplation of use of this invention.

In the presently preferred example, the interconnect structure 16 includes a high dielectric polyimide film base 25 formed on the stainless steel flexure 14. Alternatively, the film base 25 may be formed directly upon the load beam 12. A first or inner pattern of trace links 60B, 62B, is formed on the dielectric layer 25. A second dielectric layer 27 is deposited on the dielectric layer 25 over the first layer of trace links 60B and 62B. A second or outer pattern of trace links 60A, 62A is formed on the second dielectric layer 27. Conductive trace paths, such as vias 70, are defined through the second dielectric layer 27 at ends of related trace links, such that links 60A of the outer layer become connected to links 60B of the inner layer, and links 62B of the inner layer become connected to links 62A of the outer layer. This arrangement causes the links to cross over each other and realize electrical cross-talk immunity benefits attributable to a conventional twisted wire pair. We call this arrangement a "criss-cross" or "twisted" trace pattern. While vias 70 are preferred, other multi-layer interconnections are within contemplation including ball bonding, wire stitching, conductive polymer bridges, for example.

Once connected by the vias 70 the segments 60A-60B and segments 62A and 62B form the electrical service pair 60, 62. Service pair 60A-60B connects to the MR (or GMR or thin film inductive) read element, and another service pair (not shown in detail) connects to the thin film inductive write element of the head structure 26. The second service pair for the write element may be disposed linearly adjacent to the twisted service pair 60, 62 and grounded during data reading operations in order to provide additional electrostatic shielding to the twisted service pair 60, 62, as taught for example in the above-referenced U.S. Patent Application Serial No. 08/724,978, entitled: "Head Suspension with Self-Shielding Integrated Conductor Trace Array, filed on October 3, 1996 (Attorney Docket Q97-1036-US1).

While the criss-cross pattern of trace segments 60A, 60B, 62A and 62B as shown in Fig. 4 show each trace link to be substantially linear, those skilled in the art will appreciate that other non-linear geometries may be employed for the links without departing from the principles of the present invention. For example, the links may have undulating or sinuous shapes between the vias 70.

In some situations it may be desirable to provide multi-path, multi-layer criss-cross pattern with lateral as well as elevational conductor transposition for

electromagnetic interference reduction. For example, it may be desirable to have an array which periodically alters the multiple conductive paths between layers and within the same layer. Figs. 5A, 5B, 5C and 5D illustrate one example of a multi-layer, multi-conductor trace array structure 16A. The number of transitions depends on signal frequency; and the length of each section between transitions should be short, relative to wavelength of the signal as adjusted by the dielectric constant of the adjacent insulating layers. Preferably, the length of each section between transitions would be five to ten percent of the adjusted wavelength at the operating frequency. For a wavelength of one meter (300 MHz), and a dielectric constant of 3, the spacing of sections between transposition regions would lie in a range between e.g. 2.85 and 5.7 centimeters.

Four conductive trace conductor paths 60, 62, 64 and 66 are shown in the multi-layer array at a transposition area 68 in Figs. 5A-D, it being understood that there would typically be a series of transposition areas 68 along the lineal extent of the array 16A and flexible film trace array 50 for elevationally reordering the arrangement of the conductors between layers and laterally reordering the arrangement of the conductors within the same layer. The illustrated transition area 68 shows a lateral as well as elevational transposition of conductors 60, 62, 64, and 66 at the transition region 68, as follows:

$$\begin{bmatrix} 60 & 62 \\ 64 & 66 \end{bmatrix} \rightarrow \begin{bmatrix} 62' & 64' \\ 66' & 60' \end{bmatrix}$$

In the arrangement illustrated in Figs. 5A-D, there are three dielectric layers 25, 27 and 29, and three conductor layers, a lower layer formed on dielectric layer 25 which shows conductors 64 and 66 entering the transposition area 68, and which shows conductors 66' and 60' leaving the transposition area; an upper layer formed on dielectric layer 29 which shows conductors 60 and 62 entering the transposition area 68 and which shows conductors 62' and 64' leaving the transposition area; and, an intermediate bridging layer 72 formed on dielectric layer 27 which provides e.g. a bridge interconnect between vias 70 respectively connecting the conductor 60 and the conductor 60' to the bridge conductor 72 (Fig. 5D). Vias 70 extend only to the bridge interconnect conductor 72. A via 74 extends from the lower layer to the upper layer, thereby enabling a direct electrical interconnection between conductors 64 and 64' (Fig. 5C). In the physical trace arrangement illustrated in Figs. 5B, 5C and 5D, the bridge conductor 72 includes a central opening 76 sized to permit the via 74 to pass through the intermediate layer without electrical contact.

While four conductors 60, 62, 64 and 66 are shown in the Figs. 5A-D trace array 16A, the applications referenced hereinabove establish that single signal paths may be comprised of multiple conductors in order to reduce inductance, high frequency resistance and capacitance, and that more than two or three conductor layers may also be used. Also, windowing may be provided in the load beam or flexure structure to reduce trace capacitance to ground. A shielding layer may be formed over a dielectric layer covering an uppermost trace connect layer to provide electrostatic shielding of the signal paths. Other multi-layer, multi-trace layouts and arrangements are clearly within contemplation of the present invention, and the physical arrangement presented in Figs. 5B-D is by way of example only.

It should also be noted that the trace patterning to reduce electromagnetic interference is preferably extended along the flexible trace/film segment 50 leading to the preamplifier circuit 52.

The trace array structure is conventionally formed by any suitable patterning technique, whether by way of photolithography and selective etch, or by selective deposition, lamination or attachment of the conductive traces to the dielectric layers with adhesives, etc. Printing processes used in manufacturing of hybrid electronic circuit patterns may also be used to create the trace array structure. A protective overcoat of dielectric film material or solder mask may be provided over the outermost trace layer of the arrays 16 and 16A to prevent any corrosion or oxidation of the traces, and/or to provide desired mechanical properties to the structure.

Although the present invention has been described in terms of the presently preferred embodiment, i.e., a deposited conductor flexure structure which implements a gimbal, it should be clear to those skilled in the art that the present invention may also be utilized in conjunction with, for example, an integrated gimbal load beam structure, or other conductive suspension members having proximately mounted, deposited, or embedded conductors with or without insulating overcoatings. Thus, it should be understood that the instant disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art after having read the above disclosure. Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An integrated flexure/conductor structure for supporting a multi-element read/write head/slider assembly adjacent to a storage medium and for electrically interconnecting a read element of the head to read circuitry and a write element of the head to write circuitry, comprising: a generally planar conductive flexure member having a gimbal for supporting the read/write head/slider structure in proximity to a relatively moving data storage disk; a first electrical insulation layer disposed on the flexure member; a first plurality of electrical trace segments disposed on the first electrical insulation layer, a second electrical insulation layer disposed over the first plurality of electrical trace segments, a second plurality of electrical trace segments disposed on the second electrical insulation layer, and further including plural segment interconnection means passing through at least the second electrical insulation layer for interconnecting the first and second pluralities of trace segments in a predetermined transpositional interconnection arrangement to form a multi-layer conductor pair.

2. The integrated flexure/conductor structure set forth in claim 1 wherein the plural segment interconnection means comprises an arrangement of electrical vias extending through the second insulation layer for interconnecting the first and second pluralities of electrical trace segments into a criss-cross pattern forming the conductor pair.

3. The integrated flexure/conductor structure set forth in claim 1 further comprising third and fourth pluralities of electrical trace segments, forming four conductive paths, and wherein the predetermined transpositional interconnection arrangement alternately positions the four conductive paths on the first and second electrical insulation layers.

4. The integrated flexure/conductor structure set forth in claim 3 wherein the four conductive paths are laterally transposed as well as elevationally transposed between the first and second electrical insulation layers, and further comprising a third insulation layer between the first and second insulation layers, for separating a bridging layer facilitating interconnection of the laterally and elevationally transposed segments.

5. A disk drive for storing and reproducing information including a disk drive base; a storage disk rotatably mounted to the base and rotated by a disk motor; a slider for flying in proximity to a data storage surface of the storage disk; a dual-element magnetoresistive read/inductive write head for reading information from and writing

information to the storage surface; a movable actuator mounted to the base for selectively positioning the head relative to a radius of the storage surface; a read preamplifier/write driver circuit mounted on the actuator for communicating with head; and,

an integrated-conductor suspension attached to the actuator for supporting the head adjacent to the storage disk and for electrically interconnecting the head to the signal processing means, the suspension comprising:

a generally planar conductive load beam structure having a proximal actuator mounting end and a gimbaled head mounting region at a distal end for attaching the head, and including a trace conductor array comprising

a first electrical insulation layer disposed on the load beam structure;

electrical traces disposed on the first electrical insulation layer and forming first link segments of a first signal path connecting the read element with the read circuitry and second link segments of a second signal path connecting the read element with the read circuitry,

a second electrical insulation layer disposed over the first and second link segments, electrical traces disposed on the second electrical insulation layer and forming third link segments of the first signal and fourth link segments of the second signal path, and further including

plural segment interconnection means passing through at least the second electrical insulation layer for interconnecting the first and second pluralities of trace segments with the third and fourth link segments in a predetermined transpositional interconnection arrangement to form a conductor pair.

6. The disk drive set forth in claim 5 wherein the plural segment interconnection means comprises transverse connection vias passing through the second insulation layer for interconnecting the first and third link segments to form the first signal path, and for interconnecting the second and fourth link segments to form the second signal path, of the conductor pair, and wherein the first and third link segments cross over the second and fourth link segments, respectively, and become aligned and connected at the vias thereby providing a criss-cross conductor pattern.

7. A disk drive for storing and reproducing information including a disk drive base; a storage disk rotatably mounted to the base and rotated by a disk motor; a slider for flying in proximity to a data storage surface of the storage disk; a dual-element magnetoresistive read/inductive write head for reading information from and writing information to the storage surface; a movable actuator mounted to the base for selectively

positioning the head relative to a radius of the storage surface; a read preamplifier/write driver circuit of the disk drive for communicating with head; and,

an integrated-conductor suspension attached to the actuator for supporting the head adjacent to the storage disk and for electrically interconnecting the head to the signal processing means, the suspension comprising:

a generally planar conductive load beam structure having a proximal actuator mounting end and a gimbaled head mounting region at a distal end for attaching the head, and including a trace conductor array comprising

a first electrical insulation layer disposed on the load beam structure;

a first pattern of electrical traces disposed on the first electrical insulation layer and forming a first plurality of signal paths connecting the head to the circuit,

a second electrical insulation layer disposed over the first pattern of electrical traces and forming a second plurality of signal paths connecting the head to the circuit,

a plurality of transposition regions defined along the load beam structure for reordering the first and second pluralities of signal paths, and

plural trace interconnection means formed at the transposition regions for interconnecting predetermined ones of the the first and second patterns of electrical traces in a predetermined transpositional interconnection arrangement.

8. The disk drive set forth in claim 7 wherein the plural trace interconnection means comprises an arrangement of electrical vias extending through the second insulation layer to interconnect the first and second pluralities of electrical traces, such that a geometrical trace layout and the predetermined transpositional interconnection arrangement defines a multi-level criss-cross pattern for the conductor pair.

9. The disk drive set forth in claim 7 further comprising third and fourth pluralities of electrical trace segments, forming a series of signal paths, and wherein the predetermined transpositional interconnection arrangement alternates position of at least some of the series of signal paths on the first and second electrical insulation layers at the transposition regions.

10. The disk drive set forth in claim 9 wherein the series of signal paths comprises four signal paths, two signal path segments between adjacent transposition regions being formed on the first electrical insulation layer and two signal path segments

between the adjacent transposition regions being formed on the second electrical insulation layer.

11. The disk drive set forth in claim 10 further comprising a third insulation layer between the first and second insulation layers, and a bridge conductor layer formed on the third insulation layer and separated by thc third insulation layer from the first pattern of electrical traces and by the second insulation layer from the second pattern of electrical traces, for facilitating interconnection at the transposition regions of ones of the first and second path segments respectively formed on the first and second electrical insulation layers.

12. The disk drive set forth in claim 7 further comprising a flexible film interconnection structure for connnecting between the trace conductor array and the read preamplifier/write driver circuit.

13. The disk drive set forth in claim 12 wherein the flexible film interconnection structure includes a first pattern of electrical traces disposed on a thin film substrate of dielectric material and forming a first plurality of signal paths connecting the trace conductor array to the circuit,

a second electrical insulation layer disposed over the first pattern of electrical traces and forming a second plurality of signal paths connecting the trace conductor array to the circuit,

a plurality of transposition regions defined along the flexible film interconnection structure for reordering the first and second pluralities of signal paths, and

plural trace interconnection means formed at the transposition regions for interconnecting predetermined ones of the the first and second patterns of electrical traces in accordance with the predetermined transpositional interconnection arrangement.

14. The disk drive set forth in claim 7 wherein the read preamplifier/write driver circuit is mounted on the actuator.